# 4. Tides and Water Levels Requirements

## 4.1. General Project Requirements and Scope

### 4.1.1. Scope

The requirements and specifications contained in this section cover the water level and vertical datum requirements for operational support of hydrographic surveys conducted as part of the NOAA Nautical Charting Program. The scope of this support comprises the following functional areas:

1. Tide and water level requirement planning
2. Preliminary tidal zoning development
3a. Control water level station operation;
3b. Supplemental water level station installation, operation and removal
4. Data quality control, processing, and tabulation
5. Tidal datum computation and tidal datum recovery
6. Generation of water level reducers and final tidal zoning

For in-house surveys, personnel from the National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) are responsible for functional areas 1, 2, 4, 5, and 6. NOS hydrographers and CO-OPS Field Operations Division will be responsible for functional area 3 above.

For contract surveys, CO-OPS personnel are responsible for functional areas 1, 2 and 3a. NOS contract hydrographers will be responsible for functional areas 3b through 6 above. NOS continues to be responsible for operating, maintaining, and processing data from the control stations (e.g., the NWLON).

### 4.1.2. Objectives

The work performed under the requirements and specifications of this section is required for NOS major program areas of navigational products and services. The first objective for the support detailed in this section is to provide time series of water level reducers that can be applied to hydrographic soundings so that they can be corrected to chart datum. A second objective is to establish and/or recover tidal datums relative to local benchmarks at each station that can be used for continuing and future hydrographic surveys in the area. A third objective is to provide new or updated information that can be used to update NOAA tide prediction products and tidal zoning for promoting safe navigation applications.

#### 4.1.3. Planning and Preliminary Tidal Zoning

CO-OPS is responsible for all planning of tide requirements for NOS hydrographic surveys. CO-OPS will analyze historical data and tidal characteristics for each project area, specify operational NOS control stations, specify subordinate tide station locations to be installed, and provide the preliminary tidal zoning to be used during survey operations. CO-OPS will provide 6-minute interval tide predictions relative to chart datum for appropriate NOS control stations prior to each survey and will also provide historical published bench mark information available for all historical tide stations specified for reoccupation.

### 4.1.4. NOS Control Stations and Data Quality Monitoring

National Water Level Observation Network

CO-OPS manages the National Water Level Observation Network (NWLON) of approximately 175 continuously operating water level observation stations in the U.S. coastal zone, including the Great Lakes.

As most of these stations are equipped with satellite radios, near real-time (within about 3 hours of collection) raw data are made available to all users through the interface to the CO-OPS Home Page on the Web. Verified products, such as edited 6-minute data, hourly heights, high and low waters, and monthly means are made available over the Web within one to four weeks after data collection. NWLON data and accepted tidal datums are used in hydrographic surveys either provide tide reducers directly or for control for datum determination at subordinate (short-term) stations. Preliminary and verified data are made available over the Web relative to MLLW datum as a user option in the interface.

Data Quality Monitoring

CO-OPS has an in-place Continuous Operational Real-Time Monitoring System (CORMS) that provides quality control and system monitoring functions 24 hours a day or 7-days a week basis. CORMS will provide monitoring of the status and performance of all stations equipped with satellite radios using the NOS satellite message format installed by the hydrographer, as it does for all other NOS water level systems, including all NWLON stations. The CORMS system description is found in *System Development Plan, CORMS.* CORMS is a NOS provided support function to the operational field parties and does not relieve the hydrographer of responsibility for performing QC and ensuring proper gauge operation.

### 4.1.5. General Data and Reference Datum Requirements

The present NOAA Nautical Chart Reference Datum for tidal waters is Mean Lower Low Water (MLLW) based on the NOAA National Tidal Datum Epoch (NTDE) of 1960-78 as defined in the *Tide and Current Glossary*. All tidal datum computations and water level reductions will be referenced to this datum. In non tidal areas, including the Great Lakes, special low water datums have been defined for specific areas and are used as chart datum in these locations.

In some cases where historical sites are reoccupied, site datum will be zeroed to a preestablished MLLW datum held on a bench mark. In that case, data can be acquired relative to MLLW. At present, in Great Lakes areas, a special Low Water Datum relative to IGLD 85 is the reference datum.

### 4.1.6. Error Budget Considerations

The water level reducers can be a significant corrector to soundings to reduce them relative to chart datum especially in shallow water areas with relatively high ranges of tide. The errors associated with water level reducers are generally not depth dependent, however. The portion of the error of the water level reducers must be balanced against all other sounding errors to ensure that the total sounding error budget is not exceeded. The allowable contribution of the error for tides and water levels to the total survey error budget falls between 0.20m and 0.45m depending on the complexity of the tides.

The total error of the tides and water levels can be considered to have component errors of:

1) the measurement error of the gauge/sensor and processing error to refer the measurements to station datum. Gauges/sensors need to be calibrated, and sensor design and data sampling needs to include strategies to reduce measurement errors due to waves, currents, temperature, and density effects. The measurements need to be properly referenced to the bench marks and tide staffs, as appropriate and monitored for vertical stability. The measurement error, including the dynamic effects, should not exceed 0.10m at the 95% confidence level. The processing error also includes interpolation errors of the water level at the exact time of the soundings. An estimate for a typical processing error is 0.10m at the 95% confidence level.

2) the error in computation of tidal datums for the adjustment to 19-year National Tidal Datum Epoch (NTDE) periods for short term stations. The shorter the time series, the less accurate the datum. An

inappropriate control station also decreases accuracy. The NTDE does not apply in the Great Lakes. However, the accuracy of datum based on shorter time series is analogous. The estimated error of an adjusted tidal datum based on one month of data is 0.08m for the east and west coasts and 0.11m for the Gulf coast (at the 95% confidence level).

3) the error in application of tidal zoning. Tidal zoning is the extrapolation and/or interpolation of tidal characteristics from a known shore point(s) to a desired survey area using time differences and range ratios. The greater the extrapolation/interpolation, the greater the uncertainty and error. Estimates for typical errors associated with tidal zoning are 0.20m at the 95% confidence level. However, errors for this component can easily exceed 0.20m if tidal characteristics are very complex or not well defined and if there are pronounced differential effects of meteorology on the water levels across the survey area.

Project planning by NOS attempts to minimize and balance these potential sources of error through the specification of accurate reliable water level gauges, and optimization of the mix of zoning required, the number of station locations required, and the length of observations required within practical limits of the survey area and survey duration. The practical limits depend upon the tidal characteristics of the area and suitability of the coastline for the installation and operation of water level gauges.

## 4.2. Data Collection and Field Work

The hydrographer will collect continuous data series. Accurate datums cannot be computed for a month of data with a break in the water level measurement series in excess of three days. Even breaks of significantly less than three days duration will not allow for interpolation during times when strong meteorological conditions are present and in areas with little periodic tidal influence. Any break in the water level measurement series affects the accuracy of datum computations. Breaks in data also result in increased error in the tide reducers when interpolation is required to provide data at the time of soundings. At a critical measurement site where the water level measurement data cannot be transmitted or monitored during hydrographic operations, an independent backup sensor or a complete redundant water level collection system should be installed and operated during the project.

### 4.2.1. Water Level Station Requirements

Data from NOS National Water Level Observation Network (NWLON) primary stations will be provided to support hydrographic survey operations where appropriate. Data provided are relative to Chart Datum which is Mean Lower Low Water for the 19-year National Tidal Datum Epoch (NTDE).

The acquisition of water level data from subordinate locations may be required for hydrographic surveys and shall be specified by NOS in each individual set of Letter Instructions or Statement of Work. These stations shall be used to provide 6-minute time series data, tidal datum references and tidal zoning which all factor into the production of final tide reducers for specific survey areas. Station locations and requirements can be modified after station reconnaissance or as survey operations progress. Any changes must be made only after consultation between the CO-OPS and the hydrographer (and COTR if contract survey) as moving required stations to new locations may require new seven-digit station identifier numbers and new historical information.

The duration of continuous data acquisition is categorized as a 30-day minimum. Data acquisition is required from 4 hours before to 4 hours after the period of hydrography and/or shoreline verification in the applicable areas. Stations identified as “30-day” stations are the “main” subordinate stations for datum establishment, providing tide reducers for a given project, and for harmonic analysis from which harmonic constants for tide prediction can be derived. At these stations, data must be collected throughout the entire survey period in specified areas for which they are required, and not less than 30 continuous days are required for accurate datum determination. Additionally, supplemental and/or back up gauges may also be necessary based upon the complexity of the hydrodynamics and/or the severity of environmental conditions of the project area.

In non tidal areas the correctors for hydrographic soundings are simply water level measurements relative to a specified local low water level datum established for navigational purposes. Laguna Madre and Pamlico Sound are examples of such areas classified as non tidal which have special low water datums. Some river areas also have special datums due to the effects of seasonal changes on the river, e.g., Columbia River Datum is an example of this case. Great Lakes NWLON permanent stations will provide water level data referenced to an established Low Water Datum relative to International Great Lakes Datum of 1985 (IGLD '85) (see *Standing Project Instructions: Great Lakes Water Levels, June 1978*).

### 4.2.2. Water Level Measurement Systems and Data Transmissions

#### Water Level Sensor and Data Collection Platform

The water level sensor shall be a self-calibrating air acoustic, pressure (vented), or other sensor type. The sensor measurement range must be greater than the expected range of water level. Gauge/sensor systems must be calibrated prior to deployment and the calibration should be checked after removal from operations. The Data Collection Platform (DCP) shall acquire and store water level measurements at least every 6- minutes. The water level measurements shall consist of an average of at least three minutes of discrete water level samples with the period of the average centered about the six minute mark (i.e., :00, :06, :12, etc.). In addition to the average measurement, the standard deviation of the discrete water level samples which comprise the 6-minute measurements must be computed and stored. The 6-minute centered average water level data is required for compatibility with the NWLON stations and the standard deviation provides valuable data quality information regarding each measurement. The clock accuracy of a satellite radio system shall be within 5 seconds per month so that channel "stepping" does not occur. Non satellite radio systems shall have a clock accuracy of within one minute per month. Known error sources for each sensor shall be handled appropriately through ancillary measurements and/or correction algorithms. Examples are water density variations for pressure gauges, sound path air temperature differences for acoustic systems, and high frequency wave action and high velocity currents for all sensor types.

The NOS is currently using the Aquatrak® self-calibrating air acoustic sensors at the majority of the NWLON stations. (See *Next Generation Water level Measurement System (NGWLMS) Site Design, Preparation, and Installation Manual*, NOAA/NOS, January 1991 and *User's Guide for 8200 Acoustic Gauges*, NOAA/NOS, Updated August 1998). At stations where the acoustic sensor cannot be used due to freezing or the lack of a suitable structure, either a ParoScientific pressure sensor incorporated into a gas purge system or a well/float with absolute shaft angle encoder (Great Lakes Stations) are used for water level measurements. In each case the water leveling sampling/averaging scheme is as described above. For short term stations which are currently installed to support NOS hydrographic surveys, the air acoustic sensor is used whenever possible. Where the air acoustic sensor cannot be installed, NOS uses a vented strain gauge pressure sensor in a bubbler configuration (see *User's Guide for 8200 Bubbler Gauges*, NOAA/NOS, updated February 1998). When using the pressure sensor, a series of gauge/staff comparisons through a significant portion of a tidal cycle are required at the start and end of a deployment. In addition, frequent gauge/staff comparisons are also required during the deployment to assist in assuring measurement stability and minimizing processing type errors. Along with the averaging procedure above, NOS uses a combination protective well/parallel plate assembly on the acoustic sensor and a parallel plate assembly on the bubbler orifice sensor to minimize systematic measurement errors due to wave effects and current effects.

### Data Transmissions

The ability to monitor water level measurement system performance for near real-time quality assurance is essential to properly support hydrographic survey operations. Therefore, it is required that, where access to the satellite is available, the measurement system be equipped with a GOES transmitter to telemeter the data to NOS every three hours. The data transmissions must use a message format identical to the format as currently implemented in NOS' Next Generation Water Level Measurement Systems (NGWLMS). This is required to assure direct compatibility with the NOS Data Processing and Analysis Subsystem (DPAS). This data format is detailed in the reference document "*NGWLMS GOES MESSAGE FORMATTING*" (see Section 1.0). The NOS Continuous Operational Real-Time System (CORMS) will monitor all water level measurement system GOES transmissions to assure they are operating properly.

Close coordination is required between hydrographer and Requirements and Development Division (RDD) of CO-OPS for all hydrographic water level installations with satellite transmission capability. NOS will assist in acquiring assigned platform ID's, time slots, etc. At least three business days prior to the initiation of GOES data transmission in the field, information about the station number, station name, latitude, longitude, platform-ID, transmit time, channel, and serial numbers of sensors, and DCP shall be faxed, phoned, or sent to RDD. Test transmissions conducted on site are outside this requirement. This station and DCP information must be configured in DPAS before data transmissions begin so that the data will be accepted in DPAS. The documentation required prior to transmission in field is defined in the NGWLMS Site Report, Field Tide Note, or Water Level Station Report, as appropriate.

## 4.2.3. Station Installation, Operation and Removal

Hydrographers shall obtain all required permits and permissions for installation of the water level sensor(s), Data Collection Platforms (DCP), bench marks, and utilities, as required. The hydrographer shall be responsible for security and/or protective measures, as required. The hydrographer shall install all components in the manner prescribed by manufacturer, or installation manuals. The following provides general information regarding station installation, operations and maintenance, and station removal.

### Station Installation

A complete water level measurement station installation consists of the following:

(a) The installation of the water level measurement system (water level sensor(s), DCP, and satellite transmitter) and its supporting structure and a tide staff if required.

(b) The recovery and/or installation of a minimum number of bench marks and a level connection between the bench marks and the water level sensor(s), or tide staff as appropriate.

(c) The preparation of all documentation and forms.

### Operation and Maintenance

When GOES telemetry and NOS satellite message format is used, the hydrographer shall monitor the near-real time water level gauge data daily for indications of sensor malfunction or failure and for other causes of degraded or invalid data, such as marine fouling. This monitoring can be performed by accessing the CO-OPS web page (**http://www.CO-OPS.NOS.NOAA.GOV**). The data over this system are typically available for review within three to four hours after collection.

All repairs, adjustments, replacements, cleaning, or other actions potentially affecting sensor output or collection of data shall be documented in writing using appropriate maintenance forms (see section on water level station documentation below) and retained as part of the water level data record. This documentation shall include, but not be limited to, the following information: date and time of start and completion of the maintenance activity; date and time of adjustments in sensor/DCP, datum offset, or time; personnel conducting the work; parts or components replaced; component serial numbers; tests performed; etc.

### Removal

A complete removal of the water level measurement station consists of the following:

(a) Closing levels - a level connection between the bench marks and the water level sensor(s) and/or tide staff.

(b) Removal of the water level measurement system and restoration of the premises, reasonable wear and tear accepted.

(c) The preparation of all documentation, forms, data, and reports.

## 4.2.4. Tide Staffs

### Staff

The hydrographer will install a tide staff at a station if the zero of a gauge cannot be directly leveled to local bench marks such as some pressure-based bubbler gauges. Even if a pressure gauge can be leveled directly, staff readings are still required for assessment of variations in gauge performance due to density variations in the water column over time. When the station is on a pier or wharf, the staff will not be mounted to the same pile on which the water level sensor is located. The staff will be plumb. When two or more staff scales are joined to form a long staff, the hydrographer will take extra care to ensure the accuracy of the staff throughout its length. The distance between staff zero and the rod stop will be measured before the staff is installed and after it is removed.

In areas of large tidal range and long sloping beaches (i.e., Cook Inlet and the Gulf of Maine), the installation and maintenance of tide staffs can be extremely difficult and costly. In these cases, the physical installation of a tide staff(s) may be substituted by systematic leveling to the water's edge from the closest bench mark. The bench mark becomes the "staff stop" and the elevation difference to the water's edge becomes the "staff reading."

### Staff Observations

If a gauge requiring independent staff reading is installed, the installation report must be accompanied by a 3-hour set of staff-to-gauge observations documenting the proper operation of the gauge. During the first or second day of gauge operations, the gauge and staff must be read simultaneously and recorded every 6 minutes for a 3-hour period. The staff-to-gauge differences should remain constant throughout the set of observations and show no increasing or decreasing trends. Gauge time should be set to Coordinated Universal Time (UTC). The gauge and staff will be read simultaneously and recorded once a day (minimum of three days in each seven-day period) for the duration of the water level measurements. The average staff-to-gauge difference shall be applied to water level measurements to relate the data to staff zero. A higher number of independent staff readings decrease the uncertainty in transferring the measurements to station datums and the bench marks. See Figure 4.1 for an example pressure tide gauge record.

**Figure 4.1 Example - Pressure Tide Gauge Record**

**PRESSURE TIDE GAUGE RECORD**

**Station Name:**____________________________ **Station No. (7 digit #)**____________________

| Date | Time | | Staff Reading | | Gage/Staff | Gas Pressure | | Wind | Air | |
|---|---|---|---|---|---|---|---|---|---|---|
| (M,D,Y) | Gage | Correct | High | Low | Diference | Cyln | Feed | (Dir/Spd) | Temp. | Remarks |
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### 4.2.5. Bench Marks and Leveling

**Bench Marks**

A bench mark is a fixed physical object or marker (monumentation) set for stability and used as a reference to a vertical and/or horizontal datums. Bench marks in the vicinity of a water level measurement station are used as the reference for the local tidal datums derived from the water level data. The relationship between the bench marks and the water level sensor or tide staff shall be established by differential leveling.

**Number and Type of Bench Marks**

The number and type of bench marks required depends on the duration of the water level measurements. The *User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations* specifies the installation and documentation requirements for the bench marks. Each station will have one bench mark designated as the primary bench mark (PBM), which shall be leveled to on every run. The PBM is typically the most stable mark in close proximity to the water level measurement station. The contractor shall select a PBM at sites where the PBM has not already been designated. If the PBM is determined to be unstable, another mark shall be designated as PBM. The date of change and the elevation difference between the old and new PBM shall be documented. NOAA will furnish the individual NOS standard bench mark disks to be installed.

**Leveling**

At least third-order levels shall be run at short-term subordinate stations operated for less than one-year. Requirements for higher order levels will be specified in individual project instructions. Standards and specifications for the leveling are found in *Standards and Specifications for Geodetic Control Networks and Geodetic Leveling* (NOAA *Manual* NOS NGS 3). Additional field procedures used by NOS for leveling at tide stations are found in the *User’s Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations*. Electronic digital/barcode level systems are acceptable. Specifications and standards for digital levels are also found in *Standards and Specifications for Geodetic Control Networks*, and additional field procedures used by NOS for electronic leveling at water level stations, are found in the *User’s Guide for Electronic Levels*.

**Leveling Frequency**

Levels shall be run between the water level sensor(s) or tide staff and the required number of bench marks when the water level measurement station is installed, modified (e.g., water level sensor serviced), for bracketing purposes, or prior to removal. In any case, levels are required at a maximum interval of six (6) months during the station's operation, and are recommended after storms to document stability (stability discussed below).

Bracketing levels to appropriate number of marks (five for 30-day minimum stations) is required (a) if smooth tides are required 30 days or more prior to the planned removal of an applicable gauge(s), or (b) after 6 months for stations collecting data for long term hydrographic projects.

**Stability**

If there is an unresolved movement of the water level sensor or tide staff zero relative to the PBM, from one leveling to the next of greater than 0.010 m, the hydrographer shall verify the apparent movement by rerunning the levels between the sensor zero or tide staff to the PBM. This threshold of 0.010 m should not be confused with the closure tolerances used for the order and class of leveling.

#### 4.2.6. Water Level Station Documentation

The field team shall maintain a documentation package for each water level measurement station installed for hydrographic projects. The documentation package shall be forwarded to CO-OPS within 10 business days of a) installation of a station, b) performance of bracketing levels, c) gauge maintenance and repair, or d) removal of the station.

Generally, all documentation submitted (see Section 4.6.2) shall be forwarded to CO-OPS when a station is installed. For other situations, only information that has changed shall be submitted (e.g., levels and abstract for bracketing or removal levels, NGWLMS Site Report for maintenance and repair or station removal, etc.)

#### 4.2.7. Additional Field Requirements

(a) Generally upon completion of the data acquisition for each gauge installed, the data must be sent all together for 30-day minimum gauges unless the data are transmitted via satellite. For long term stations running more than three months, the data will be sent periodically (monthly) unless the data are transmitted via satellite.

(b) All water level data from a gauge shall be downloaded and backed up at least weekly on diskettes whether the gauge data are sent via satellite or not.

(c) For new stations that do not have station numbers assigned, CO-OPS shall be contacted once the location of the gauge has been finalized and provide latitude and longitude of the gauge site at least three business days prior to actual installation of the gauge in field. CO-OPS will assign a new station number within three business days and inform the hydrographer.

(d) The progress sketch shall show the field sheet, layout, area of hydrography, gauge locations, and other information as appropriate. Verify the location of the gauge as shown on the progress sketch, bench mark and tide station location sketch, field tide note, NGWLMS Site Report (Tide Station Report or Great Lakes Water Level Station Report).

### 4.3. Data Processing and Reduction

#### 4.3.1. Data Quality Control

The required output product used in generation of tide reducers and for a tidal datum determination is a continuous time series of 6-minute interval water level data for the desired time period of hydrography and for a specified minimum time period from which to derive tidal datums. CO-OPS will monitor the installed system operation information for all gauges equipped with GOES satellite radios. The 6-minute interval water level data from the water level gauges shall be quality controlled to NOS standards by the contractor for invalid and suspect data as a final review prior to product generation and application. This includes checking for data gaps, data discontinuities, datum shifts, anomalous data points, data points outside of expected tolerances such as expected maximum and minimum values and for anomalous trends in the elevations due to sensor drift or vertical movement of the tide station components and bench marks.

Quality control should include comparisons with simultaneous data from backup gauges, predicted tides or data from nearby stations. Data editing and gap filling shall use documented mathematically sound algorithms and procedures and an audit trail shall be used to track all changes and edits to observed data. All inferred data shall be appropriately flagged. Water level measurements from each station shall be related to a single, common datum, referred to as Station Datum. Station datum is an arbitrary datum and should not be confused with a tidal datum such as MLLW. All discontinuities, jumps, or other changes in the gauge record (refer to the specific gauge user's guide) that may be due to vertical movement of any gauge, staff, or bench marks shall be fully documented. All data shall be recorded on UTC and the units of measurement shall be properly denoted on all hardcopy output and digital files.

### 4.3.2. Data Processing and Tabulation of the Tide

The continuous 6-minute interval water level data are used to generate the standard tabulation output products. These products include the times and heights of the high and low waters, hourly heights, maximum and minimum monthly water levels, and monthly mean values for the desired parameters. Examples of these tabulation products are found in Figures 4.1 and 4.2 for tide stations and 4.3 for Great Lakes stations. The times and heights of the high and low waters shall be derived from appropriate curve-fitting of the 6-minute interval data. For purposes of tabulation of the high and low tides and not non tidal high frequency noise, successive high and low tides shall not be tabulated unless they are greater than 2.0 hours apart in time and 0.030 meters different in elevation. Hourly heights shall be derived from every 6-minute value observed on the hour. Monthly mean sea level and monthly mean water level shall be computed from the average of the hourly heights over each calendar month of data. Data shall be tabulated relative to a documented consistent station datum such as tide staff zero, arbitrary station datum, MLLW, etc. over the duration of the data observations. Descriptions of general procedures used in tabulation are also found in the *Tide and Current Glossary, Manual of Tide Observations,* and *Tidal Datum Planes.*

### 4.3.3. Computation of Monthly Means

Monthly means are derived on a calendar month basis in accordance with the definitions for the monthly mean parameters are found in the Tide and Current Glossary. Examples of the desired monthly means are found in figures 4.2 and 4.4. For purposes of monthly mean computation, monthly means will not be computed if gaps in data are greater than three consecutive days.

### 4.3.4. Data Editing and Gap Filling Specifications

When backup sensor data are not available, data gaps in 6-minute data shall not be filled if the gaps are greater than three consecutive days in length. Data gap filling shall use documented mathematically and scientifically sound algorithms and procedures and an audit trail shall be used to track all gap-fills in observed data. Data gaps of less than 3-hours can be inferred using interpolation and curve-fitting techniques. Data gaps of longer than three hours shall use external data sources such as data from a nearby station. All data derived through gap-filling procedures shall be marked as inferred. Individual hourly heights, high and low waters, and daily means derived from inferred data shall also be designated as inferred.

## Figure 4.2

TIDES, HIGH AND LOW WATERS July 1998

National Ocean Service (NOAA)

Water Level Heights in meters on Station Datum

Station: 9414290 SAN FRANCISCO, SAN FRANCISCO BAY , CA

Time Meridian: 0 W Tide Type: Mixed

| DAY | HIGH TIME | HIGH HEIGHT | LOW TIME | LOW HEIGHT | DAY | HIGH TIME | HIGH HEIGHT | LOW TIME | LOW HEIGHT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | > 1.4 | 3.337 | 6.8 | 2.521 | 16 | > 0.6 | 3.550 | 6.2 | 2.343 |
| | 12.6 | 2.996 | > 18.5 | 2.253 | | 12.6 | 3.187 | > 18.1 | 2.195 |
| 2 | > 2.0 | 3.393 | 7.8 | 2.434 | 17 | > 1.4 | 3.654 | 7.4 | 2.205 |
| | 13.9 | 2.950 | > 19.4 | 2.406 | | 14.1 | 3.096 | 19.0 | 2.335 |
| 3 | > 2.6 | 3.458 | > 9.1 | 2.367 | 18 | > 2.2 | 3.725 | > 8.6 | 2.054 |
| | 15.2 | 2.941 | 20.1 | 2.498 | | 15.6 | 3.132 | 20.2 | 2.504 |
| 4 | > 3.2 | 3.524 | > 9.7 | 2.210 | 19 | > 3.1 | 3.819 | > 9.7 | 1.891 |
| | 16.5 | 2.988 | 21.1 | 2.612 | | 16.9 | 3.188 | 21.5 | 2.586 |
| 5 | > 4.0 | 3.584 | > 10.3 | 2.018 | 20 | > 4.1 | 3.899 | > 10.7 | 1.763 |
| | 17.6 | 3.054 | 22.0 | 2.644 | | 18.0 | 3.267 | 22.5 | 2.597 |
| 6 | > 4.6 | 3.656 | > 11.1 | 1.913 | 21 | > 4.9 | 3.903 | > 11.6 | 1.654 |
| | 18.3 | 3.124 | 22.7 | 2.682 | | 18.8 | 3.309 | 23.4 | 2.583 |
| 7 | > 5.1 | 3.711 | > 11.8 | 1.812 | 22 | > 6.0 | 3.884 | | |
| | 19.1 | 3.194 | 23.4 | 2.697 | | 19.6 | 3.347 | >12.4 | 1.587 |
| 8 | > 5.8 | 3.754 | | | 23 | > 6.4 | 3.880 | 0.2 | 2.587 |
| | 19.7 | 3.223 | > 12.4 | 1.730 | | 20.3 | 3.390 | >13.1 | 1.611 |
| 9 | > 6.3 | 3.789 | 0.1 | 2.703 | 24 | > 7.4 | 3.833 | 1.1 | 2.586 |
| | 20.4 | 3.285 | > 13.1 | 1.669 | | 20.9 | 3.409 | > 13.9 | 1.659 |
| 10 | > 7.3 | 3.795 | 0.9 | 2.709 | 25 | > 8.1 | 3.780 | 1.7 | 2.562 |
| | 21.1 | 3.306 | > 13.7 | 1.627 | | 21.6 | 3.445 | > 14.5 | 1.719 |
| 11 | > 8.0 | 3.712 | 1.6 | 2.614 | 26 | > 8.7 | 3.668 | 2.6 | 2.564 |
| | 21.7 | 3.302 | > 14.4 | 1.579 | | 22.2 | 3.437 | > 14.9 | 1.826 |
| 12 | > 8.8 | 3.639 | 2.5 | 2.584 | 27 | > 9.3 | 3.510 | 3.2 | 2.549 |
| | 22.3 | 3.356 | > 15.1 | 1.609 | | >22.8 | 3.416 | > 15.6 | 1.932 |
| 13 | > 9.3 | 3.547 | 3.1 | 2.530 | 28 | 10.1 | 3.356 | 4.1 | 2.538 |
| | 23.1 | 3.419 | > 15.6 | 1.692 | | >23.5 | 3.430 | > 16.1 | 2.042 |
| 14 | 10.1 | 3.443 | 4.1 | 2.522 | 29 | 10.9 | 3.202 | 5.0 | 2.495 |
| | > 23.9 | 3.484 | > 16.5 | 1.800 | | | | > 16.6 | 2.199 |
| 15 | 11.3 | 3.282 | 5.1 | 2.422 | 30 | > 0.1 | 3.432 | 5.9 | 2.492 |
| | | | > 17.0 | 1.967 | | 12.0 | 3.099 | > 17.3 | 2.402 |
| | | | | | 31 | > 0.8 | 3.472 | > 6.9 | 2.431 |
| | | | | | | 13.1 | 3.018 | 18.5 | 2.513 |

HIGHEST TIDE: 3.903 4.9 HRS Jul 21 1998

LOWEST TIDE: 1.579 14.4 HRS Jul 11 1998

MONTHLY MEANS FOR July 1998

HWL 3.903
MHHW 3.641 DHQ 0.208
MHW 3.433 GT 1.720
MTL 2.832 MN 1.203
DTL 2.781
MSL 2.816
MLW 2.230 DLQ 0.309
MLLW 1.921
LWL 1.579
HWI 7.570 HRS
LWI 0.760 HRS

> higher high/lower low waters [ ] denotes inferred water level values Data Status: Verified

# Figure 4.3

HOURLY WATER LEVELS

National Ocean Service (NOAA) July 1998

Water Level Heights in meters on Station Datum

Station: 9414290 SAN FRANCISCO, SAN FRANCISCO BAY , CA Time Meridian 0 W Tide Type: Mixed

| HOUR | Jul 1 | Jul 2 | Jul 3 | Jul 4 | Jul 5 | Jul 6 | Jul 7 | Jul 8 | Jul 9 | Jul 10 | Jul 11 | Jul 12 | Jul 13 | Jul 14 | Jul 15 | Jul 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00 | 3.247 | 3.183 | 3.119 | 3.052 | 2.936 | 2.837 | 2.770 | 2.724 | 2.717 | 2.763 | 2.814 | 2.960 | 3.152 | 3.354 | 3.481 | 3.529 |
| 01 | 3.329 | 3.333 | 3.319 | 3.274 | 3.157 | 3.066 | 2.972 | 2.851 | 2.762 | 2.694 | 2.637 | 2.723 | 2.901 | 3.162 | 3.365 | 3.517 |
| 02 | 3.311 | 3.391 | 3.449 | 3.437 | 3.378 | 3.293 | 3.173 | 3.060 | 2.913 | 2.799 | 2.627 | 2.602 | 2.653 | 2.868 | 3.123 | 3.395 |
| 03 | 3.164 | 3.312 | 3.463 | 3.526 | 3.526 | 3.504 | 3.423 | 3.298 | 3.171 | 2.988 | 2.750 | 2.618 | 2.529 | 2.621 | 2.792 | 3.103 |
| 04 | 2.948 | 3.158 | 3.338 | 3.469 | 3.595 | 3.629 | 3.617 | 3.555 | 3.420 | 3.261 | 2.985 | 2.755 | 2.606 | 2.523 | 2.523 | 2.741 |
| 05 | 2.725 | 2.914 | 3.091 | 3.304 | 3.474 | 3.628 | 3.714 | 3.707 | 3.652 | 3.519 | 3.247 | 3.012 | 2.757 | 2.576 | 2.423 | 2.459 |
| 06 | 2.558 | 2.651 | 2.811 | 3.012 | 3.209 | 3.430 | 3.640 | 3.740 | 3.782 | 3.711 | 3.508 | 3.252 | 2.986 | 2.745 | 2.472 | 2.302 |
| 07 | 2.528 | 2.451 | 2.531 | 2.651 | 2.833 | 3.112 | 3.342 | 3.580 | 3.746 | 3.785 | 3.668 | 3.485 | 3.217 | 2.954 | 2.619 | 2.399 |
| 08 | 2.581 | 2.453 | 2.387 | 2.366 | 2.448 | 2.653 | 2.915 | 3.225 | 3.496 | 3.677 | 3.715 | 3.628 | 3.433 | 3.155 | 2.804 | 2.480 |
| 09 | 2.648 | 2.510 | 2.375 | 2.228 | 2.133 | 2.243 | 2.435 | 2.701 | 3.060 | 3.348 | 3.540 | 3.626 | 3.535 | 3.354 | 2.997 | 2.651 |
| 10 | 2.778 | 2.568 | 2.400 | 2.229 | 2.017 | 1.994 | 2.057 | 2.236 | 2.477 | 2.819 | 3.159 | 3.410 | 3.510 | 3.444 | 3.185 | 2.870 |
| 11 | 2.890 | 2.696 | 2.494 | 2.280 | 2.057 | 1.909 | 1.859 | 1.919 | 2.081 | 2.327 | 2.576 | 2.970 | 3.257 | 3.389 | 3.283 | 3.040 |
| 12 | 2.976 | 2.813 | 2.643 | 2.431 | 2.159 | 1.972 | 1.826 | 1.719 | 1.774 | 1.922 | 2.101 | 2.422 | 2.818 | 3.165 | 3.248 | 3.162 |
| 13 | 2.995 | 2.917 | 2.750 | 2.581 | 2.327 | 2.124 | 1.913 | 1.756 | 1.674 | 1.667 | 1.781 | 2.000 | 2.350 | 2.735 | 3.051 | 3.175 |
| 14 | 2.904 | 2.945 | 2.897 | 2.760 | 2.559 | 2.338 | 2.117 | 1.908 | 1.744 | 1.633 | 1.588 | 1.706 | 1.946 | 2.305 | 2.737 | 3.069 |
| 15 | 2.742 | 2.903 | 2.922 | 2.898 | 2.778 | 2.611 | 2.387 | 2.154 | 1.944 | 1.759 | 1.625 | 1.612 | 1.732 | 1.965 | 2.365 | 2.831 |
| 16 | 2.505 | 2.783 | 2.909 | 2.986 | 2.937 | 2.862 | 2.683 | 2.455 | 2.260 | 2.014 | 1.791 | 1.690 | 1.697 | 1.794 | 2.053 | 2.492 |
| 17 | 2.359 | 2.594 | 2.814 | 2.976 | 3.040 | 3.034 | 2.954 | 2.786 | 2.585 | 2.366 | 2.084 | 1.911 | 1.852 | 1.854 | 1.971 | 2.258 |
| 18 | 2.250 | 2.473 | 2.649 | 2.915 | 3.028 | 3.137 | 3.124 | 3.015 | 2.936 | 2.739 | 2.449 | 2.242 | 2.074 | 1.986 | 2.020 | 2.177 |
| 19 | 2.272 | 2.401 | 2.550 | 2.773 | 2.960 | 3.099 | 3.190 | 3.187 | 3.141 | 3.021 | 2.814 | 2.618 | 2.419 | 2.256 | 2.193 | 2.269 |
| 20 | 2.336 | 2.413 | 2.484 | 2.647 | 2.812 | 2.990 | 3.149 | 3.215 | 3.271 | 3.239 | 3.094 | 2.975 | 2.797 | 2.595 | 2.462 | 2.415 |
| 21 | 2.508 | 2.514 | 2.527 | 2.637 | 2.690 | 2.843 | 2.999 | 3.128 | 3.251 | 3.310 | 3.275 | 3.220 | 3.131 | 2.954 | 2.781 | 2.677 |
| 22 | 2.736 | 2.685 | 2.631 | 2.636 | 2.634 | 2.709 | 2.835 | 2.982 | 3.130 | 3.233 | 3.280 | 3.369 | 3.339 | 3.242 | 3.104 | 2.961 |
| 23 | 2.965 | 2.912 | 2.814 | 2.752 | 2.703 | 2.700 | 2.688 | 2.779 | 2.916 | 3.063 | 3.177 | 3.322 | 3.422 | 3.417 | 3.336 | 3.284 |
| Mean | 2.761 | 2.791 | 2.807 | 2.826 | 2.808 | 2.822 | 2.824 | 2.820 | 2.829 | 2.819 | 2.762 | 2.755 | 2.755 | 2.767 | 2.766 | 2.802 |

| HOUR | Jul 17 | Jul 18 | Jul 19 | Jul 20 | Jul 21 | Jul 22 | Jul 23 | Jul 24 | Jul 25 | Jul 26 | Jul 27 | Jul 28 | Jul 29 | Jul 30 | Jul 31 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00 | 3.514 | 3.373 | 3.180 | 2.993 | 2.778 | 2.625 | 2.586 | 2.678 | 2.821 | 3.048 | 3.228 | 3.317 | 3.411 | 3.444 | 3.438 | |
| 01 | 3.654 | 3.617 | 3.485 | 3.264 | 3.035 | 2.810 | 2.649 | 2.586 | 2.613 | 2.749 | 2.951 | 3.122 | 3.270 | 3.357 | 3.466 | |
| 02 | 3.620 | 3.720 | 3.720 | 3.573 | 3.322 | 3.071 | 2.848 | 2.682 | 2.573 | 2.590 | 2.680 | 2.834 | 3.030 | 3.195 | 3.394 | Monthly |
| 03 | 3.427 | 3.686 | 3.818 | 3.785 | 3.641 | 3.379 | 3.133 | 2.884 | 2.694 | 2.576 | 2.550 | 2.625 | 2.735 | 2.937 | 3.148 | Max HWL |
| 04 | 3.111 | 3.433 | 3.737 | 3.907 | 3.840 | 3.659 | 3.444 | 3.201 | 2.926 | 2.761 | 2.591 | 2.538 | 2.547 | 2.704 | 2.888 | 04:54/21 |
| 05 | 2.704 | 3.048 | 3.487 | 3.775 | 3.898 | 3.849 | 3.697 | 3.460 | 3.206 | 2.978 | 2.759 | 2.586 | 2.487 | 2.523 | 2.660 | 3.903 |
| 06 | 2.398 | 2.607 | 3.017 | 3.452 | 3.745 | 3.887 | 3.866 | 3.717 | 3.505 | 3.247 | 2.976 | 2.757 | 2.553 | 2.486 | 2.467 | |
| 07 | 2.215 | 2.254 | 2.539 | 2.948 | 3.376 | 3.678 | 3.851 | 3.828 | 3.704 | 3.501 | 3.210 | 2.928 | 2.697 | 2.545 | 2.448 | |
| 08 | 2.255 | 2.073 | 2.167 | 2.436 | 2.810 | 3.269 | 3.593 | 3.770 | 3.778 | 3.652 | 3.390 | 3.150 | 2.860 | 2.659 | 2.477 | Monthly |
| 09 | 2.319 | 2.064 | 1.953 | 2.018 | 2.299 | 2.662 | 3.083 | 3.430 | 3.637 | 3.659 | 3.504 | 3.302 | 3.031 | 2.809 | 2.571 | Min LWL |
| 10 | 2.483 | 2.155 | 1.884 | 1.806 | 1.896 | 2.146 | 2.526 | 2.942 | 3.284 | 3.486 | 3.479 | 3.358 | 3.144 | 2.948 | 2.725 | 14:24/11 |
| 11 | 2.691 | 2.304 | 1.993 | 1.757 | 1.696 | 1.794 | 2.071 | 2.397 | 2.758 | 3.107 | 3.252 | 3.294 | 3.203 | 3.055 | 2.856 | 1.579 |
| 12 | 2.876 | 2.544 | 2.195 | 1.877 | 1.664 | 1.603 | 1.743 | 1.981 | 2.282 | 2.618 | 2.907 | 3.090 | 3.119 | 3.107 | 2.975 | |
| 13 | 3.037 | 2.784 | 2.453 | 2.094 | 1.808 | 1.637 | 1.621 | 1.723 | 1.924 | 2.215 | 2.471 | 2.741 | 2.953 | 3.037 | 3.031 | |
| 14 | 3.088 | 2.995 | 2.738 | 2.387 | 2.076 | 1.816 | 1.662 | 1.644 | 1.740 | 1.919 | 2.149 | 2.402 | 2.658 | 2.905 | 2.975 | Monthly |
| 15 | 3.038 | 3.104 | 2.978 | 2.738 | 2.434 | 2.122 | 1.918 | 1.797 | 1.762 | 1.827 | 1.956 | 2.144 | 2.396 | 2.676 | 2.908 | Mean |
| 16 | 2.880 | 3.119 | 3.134 | 3.028 | 2.790 | 2.510 | 2.249 | 2.056 | 1.942 | 1.882 | 1.950 | 2.016 | 2.231 | 2.493 | 2.725 | MSL |
| 17 | 2.621 | 3.011 | 3.191 | 3.220 | 3.078 | 2.887 | 2.646 | 2.422 | 2.219 | 2.117 | 2.061 | 2.118 | 2.218 | 2.398 | 2.595 | 2.816 |
| 18 | 2.400 | 2.812 | 3.107 | 3.284 | 3.266 | 3.162 | 3.018 | 2.791 | 2.604 | 2.412 | 2.302 | 2.244 | 2.299 | 2.432 | 2.508 | |
| 19 | 2.323 | 2.600 | 2.938 | 3.179 | 3.300 | 3.316 | 3.273 | 3.162 | 2.978 | 2.775 | 2.615 | 2.496 | 2.465 | 2.490 | 2.527 | |
| 20 | 2.402 | 2.513 | 2.731 | 3.013 | 3.210 | 3.336 | 3.394 | 3.345 | 3.271 | 3.109 | 2.939 | 2.795 | 2.688 | 2.663 | 2.620 | |
| 21 | 2.554 | 2.550 | 2.605 | 2.755 | 3.012 | 3.214 | 3.345 | 3.401 | 3.415 | 3.335 | 3.215 | 3.075 | 2.963 | 2.884 | 2.766 | |
| 22 | 2.789 | 2.698 | 2.619 | 2.612 | 2.735 | 2.975 | 3.189 | 3.316 | 3.427 | 3.428 | 3.369 | 3.310 | 3.184 | 3.109 | 2.984 | |
| 23 | 3.073 | 2.920 | 2.760 | 2.631 | 2.613 | 2.707 | 2.912 | 3.118 | 3.300 | 3.400 | 3.407 | 3.429 | 3.373 | 3.308 | 3.178 | |
| Mean | 2.811 | 2.833 | 2.851 | 2.855 | 2.847 | 2.838 | 2.847 | 2.847 | 2.848 | 2.850 | 2.830 | 2.820 | 2.813 | 2.840 | 2.847 | |

[ ] denotes inferred water level values Data Status: Verified

# Figure 4.4

HOURLY WATER LEVELS

National Ocean Service (NOAA) July 1998

Water Level Heights in meters IGLD (1985)

Station: 9052030 Oswego, Lake Ontario , NY Time Meridian: 75 W Data Type: Great Lakes

| HOUR | Jul 1 | Jul 2 | Jul 3 | Jul 4 | Jul 5 | Jul 6 | Jul 7 | Jul 8 | Jul 9 | Jul 10 | Jul 11 | Jul 12 | Jul 13 | Jul 14 | Jul 15 | Jul 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 75.21 | 75.21 | 75.19 | 75.18 | 75.19 | 75.17 | 75.15 | 75.17 | 75.17 | 75.20 | 75.21 | 75.21 | 75.20 | 75.17 | 75.17 | 75.17 |
| 02 | 75.25 | 75.21 | 75.19 | 75.19 | 75.22 | 75.14 | 75.17 | 75.16 | 75.19 | 75.19 | 75.20 | 75.22 | 75.18 | 75.17 | 75.18 | 75.16 |
| 03 | 75.26 | 75.21 | 75.19 | 75.17 | 75.19 | 75.18 | 75.18 | 75.16 | 75.16 | 75.19 | 75.21 | 75.19 | 75.18 | 75.18 | 75.15 | 75.17 |
| 04 | 75.25 | 75.20 | 75.19 | 75.20 | 75.21 | 75.18 | 75.17 | 75.16 | 75.17 | 75.20 | 75.21 | 75.18 | 75.17 | 75.18 | 75.16 | 75.16 |
| 05 | 75.25 | 75.21 | 75.20 | 75.19 | 75.21 | 75.18 | 75.17 | 75.20 | 75.20 | 75.18 | 75.21 | 75.20 | 75.19 | 75.17 | 75.19 | 75.16 |
| 06 | 75.25 | 75.21 | 75.19 | 75.20 | 75.20 | 75.19 | 75.17 | 75.16 | 75.19 | 75.20 | 75.20 | 75.20 | 75.17 | 75.17 | 75.14 | 75.15 |
| 07 | 75.25 | 75.20 | 75.19 | 75.19 | 75.19 | 75.17 | 75.18 | 75.20 | 75.20 | 75.19 | 75.21 | 75.20 | 75.18 | 75.17 | 75.14 | 75.17 |
| 08 | 75.24 | 75.21 | 75.19 | 75.21 | 75.20 | 75.17 | 75.17 | 75.14 | 75.19 | 75.20 | 75.22 | 75.20 | 75.19 | 75.15 | 75.18 | 75.15 |
| 09 | 75.24 | 75.21 | 75.19 | 75.20 | 75.19 | 75.19 | 75.16 | 75.17 | 75.18 | 75.18 | 75.22 | 75.20 | 75.19 | 75.18 | 75.16 | 75.14 |
| 10 | 75.24 | 75.20 | 75.19 | 75.18 | 75.19 | 75.18 | 75.16 | 75.20 | 75.17 | 75.20 | 75.22 | 75.22 | 75.18 | 75.18 | 75.17 | 75.16 |
| 11 | 75.23 | 75.19 | 75.17 | 75.18 | 75.20 | 75.18 | 75.15 | 75.15 | 75.19 | 75.20 | 75.22 | 75.20 | 75.19 | 75.18 | 75.16 | 75.15 |
| 12 | 75.22 | 75.21 | 75.18 | 75.18 | 75.17 | 75.17 | 75.17 | 75.16 | 75.17 | 75.19 | 75.22 | 75.20 | 75.18 | 75.18 | 75.17 | 75.16 |
| 13 | 75.22 | 75.20 | 75.18 | 75.19 | 75.18 | 75.16 | 75.16 | 75.15 | 75.17 | 75.18 | 75.21 | 75.19 | 75.19 | 75.17 | 75.16 | 75.16 |
| 14 | 75.23 | 75.20 | 75.19 | 75.21 | 75.18 | 75.19 | 75.14 | 75.15 | 75.16 | 75.18 | 75.20 | 75.22 | 75.17 | 75.17 | 75.18 | 75.17 |
| 15 | 75.22 | 75.21 | 75.17 | 75.19 | 75.17 | 75.15 | 75.14 | 75.18 | 75.17 | 75.19 | 75.20 | 75.18 | 75.18 | 75.17 | 75.17 | 75.17 |
| 16 | 75.21 | 75.20 | 75.19 | 75.18 | 75.19 | 75.16 | 75.18 | 75.18 | 75.17 | 75.19 | 75.19 | 75.19 | 75.17 | 75.16 | 75.16 | 75.16 |
| 17 | 75.21 | 75.20 | 75.20 | 75.21 | 75.20 | 75.17 | 75.17 | 75.18 | 75.17 | 75.19 | 75.20 | 75.18 | 75.17 | 75.17 | 75.17 | 75.15 |
| 18 | 75.22 | 75.20 | 75.20 | 75.21 | 75.21 | 75.20 | 75.18 | 75.18 | 75.15 | 75.17 | 75.20 | 75.18 | 75.16 | 75.15 | 75.16 | 75.16 |
| 19 | 75.21 | 75.20 | 75.19 | 75.21 | 75.19 | 75.19 | 75.18 | 75.20 | 75.18 | 75.22 | 75.19 | 75.19 | 75.17 | 75.16 | 75.16 | 75.17 |
| 20 | 75.20 | 75.22 | 75.19 | 75.25 | 75.19 | 75.17 | 75.18 | 75.18 | 75.20 | 75.22 | 75.20 | 75.20 | 75.16 | 75.16 | 75.16 | 75.13 |
| 21 | 75.20 | 75.18 | 75.18 | 75.15 | 75.19 | 75.19 | 75.15 | 75.19 | 75.22 | 75.18 | 75.21 | 75.19 | 75.18 | 75.16 | 75.15 | 75.17 |
| 22 | 75.21 | 75.20 | 75.17 | 75.17 | 75.19 | 75.18 | 75.19 | 75.17 | 75.23 | 75.20 | 75.21 | 75.19 | 75.18 | 75.18 | 75.15 | 75.13 |
| 23 | 75.20 | 75.19 | 75.17 | 75.24 | 75.19 | 75.16 | 75.18 | 75.19 | 75.22 | 75.22 | 75.21 | 75.17 | 75.18 | 75.16 | 75.17 | 75.13 |
| 24 | 75.21 | 75.20 | 75.17 | 75.20 | 75.18 | 75.17 | 75.17 | 75.19 | 75.18 | 75.21 | 75.21 | 75.18 | 75.18 | 75.15 | 75.16 | 75.15 |
| Mean | 75.23 | 75.20 | 75.19 | 75.19 | 75.19 | 75.18 | 75.17 | 75.17 | 75.18 | 75.20 | 75.21 | 75.19 | 75.18 | 75.17 | 75.16 | 75.16 |

| HOUR | Jul 17 | Jul 18 | Jul 19 | Jul 20 | Jul 21 | Jul 22 | Jul 23 | Jul 24 | Jul 25 | Jul 26 | Jul 27 | Jul 28 | Jul 29 | Jul 30 | Jul 31 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 75.17 | 75.17 | 75.14 | 75.12 | 75.13 | 75.14 | 75.11 | 75.16 | 75.14 | 75.11 | 75.09 | 75.07 | 75.07 | 75.10 | 75.09 | |
| 02 | 75.17 | 75.18 | 75.14 | 75.16 | 75.12 | 75.16 | 75.12 | 75.16 | 75.14 | 75.10 | 75.08 | 75.09 | 75.06 | 75.11 | 75.08 | |
| 03 | 75.16 | 75.19 | 75.15 | 75.15 | 75.11 | 75.16 | 75.12 | 75.15 | 75.13 | 75.10 | 75.08 | 75.06 | 75.06 | 75.10 | 75.08 | Monthly |
| 04 | 75.17 | 75.18 | 75.14 | 75.14 | 75.13 | 75.15 | 75.10 | 75.14 | 75.14 | 75.10 | 75.07 | 75.09 | 75.02 | 75.09 | 75.08 | Max HWL |
| 05 | 75.16 | 75.18 | 75.16 | 75.13 | 75.14 | 75.13 | 75.14 | 75.16 | 75.13 | 75.10 | 75.06 | 75.11 | 75.07 | 75.08 | 75.08 | 03:00/01 |
| 06 | 75.17 | 75.16 | 75.15 | 75.16 | 75.10 | 75.17 | 75.12 | 75.16 | 75.12 | 75.10 | 75.06 | 75.07 | 75.16 | 75.07 | 75.08 | 75.259 |
| 07 | 75.16 | 75.16 | 75.17 | 75.14 | 75.12 | 75.13 | 75.14 | 75.14 | 75.13 | 75.10 | 75.07 | 75.06 | 75.14 | 75.07 | 75.07 | |
| 08 | 75.16 | 75.16 | 75.14 | 75.15 | 75.15 | 75.12 | 75.14 | 75.16 | 75.13 | 75.10 | 75.06 | 75.08 | 75.11 | 75.05 | 75.07 | |
| 09 | 75.15 | 75.15 | 75.11 | 75.14 | 75.12 | 75.20 | 75.15 | 75.17 | 75.13 | 75.11 | 75.06 | 75.06 | 75.10 | 75.08 | 75.07 | Monthly |
| 10 | 75.16 | 75.15 | 75.11 | 75.14 | 75.11 | 75.18 | 75.10 | 75.15 | 75.13 | 75.12 | 75.08 | 75.07 | 75.11 | 75.07 | 75.06 | Min LWL |
| 11 | 75.16 | 75.16 | 75.13 | 75.14 | 75.11 | 75.16 | 75.11 | 75.16 | 75.12 | 75.11 | 75.08 | 75.06 | 75.11 | 75.06 | 75.07 | 04:00/29 |
| 12 | 75.16 | 75.17 | 75.16 | 75.14 | 75.12 | 75.12 | 75.13 | 75.14 | 75.11 | 75.11 | 75.09 | 75.07 | 75.12 | 75.10 | 75.07 | 75.021 |
| 13 | 75.16 | 75.15 | 75.14 | 75.14 | 75.12 | 75.14 | 75.13 | 75.14 | 75.11 | 75.10 | 75.07 | 75.05 | 75.08 | 75.08 | 75.07 | |
| 14 | 75.16 | 75.17 | 75.13 | 75.15 | 75.10 | 75.11 | 75.14 | 75.14 | 75.10 | 75.11 | 75.06 | 75.08 | 75.08 | 75.08 | 75.06 | |
| 15 | 75.17 | 75.16 | 75.13 | 75.13 | 75.12 | 75.12 | 75.12 | 75.13 | 75.11 | 75.09 | 75.07 | 75.06 | 75.07 | 75.08 | 75.05 | Monthly |
| 16 | 75.16 | 75.16 | 75.13 | 75.13 | 75.13 | 75.14 | 75.14 | 75.13 | 75.12 | 75.09 | 75.08 | 75.05 | 75.09 | 75.05 | 75.06 | Mean |
| 17 | 75.18 | 75.16 | 75.13 | 75.13 | 75.08 | 75.11 | 75.16 | 75.13 | 75.10 | 75.07 | 75.08 | 75.07 | 75.08 | 75.09 | 75.06 | MSL |
| 18 | 75.17 | 75.15 | 75.14 | 75.16 | 75.12 | 75.13 | 75.13 | 75.13 | 75.10 | 75.07 | 75.08 | 75.06 | 75.08 | 75.09 | 75.06 | 75.152 |
| 19 | 75.16 | 75.16 | 75.13 | 75.14 | 75.11 | 75.11 | 75.10 | 75.14 | 75.10 | 75.08 | 75.06 | 75.05 | 75.07 | 75.09 | 75.06 | |
| 20 | 75.17 | 75.16 | 75.16 | 75.15 | 75.12 | 75.13 | 75.16 | 75.14 | 75.11 | 75.09 | 75.06 | 75.07 | 75.09 | 75.07 | 75.06 | |
| 21 | 75.18 | 75.14 | 75.11 | 75.13 | 75.16 | 75.12 | 75.17 | 75.14 | 75.11 | 75.08 | 75.07 | 75.05 | 75.09 | 75.07 | 75.04 | |
| 22 | 75.18 | 75.15 | 75.14 | 75.13 | 75.10 | 75.15 | 75.17 | 75.14 | 75.11 | 75.08 | 75.07 | 75.06 | 75.09 | 75.08 | 75.06 | |
| 23 | 75.18 | 75.14 | 75.14 | 75.12 | 75.09 | 75.14 | 75.18 | 75.14 | 75.11 | 75.08 | 75.09 | 75.05 | 75.10 | 75.08 | 75.05 | |
| 24 | 75.19 | 75.14 | 75.11 | 75.11 | 75.09 | 75.12 | 75.17 | 75.15 | 75.11 | 75.09 | 75.10 | 75.08 | 75.09 | 75.09 | 75.06 | |
| Mean | 75.17 | 75.16 | 75.14 | 75.14 | 75.12 | 75.14 | 75.14 | 75.15 | 75.12 | 75.10 | 75.07 | 75.07 | 75.09 | 75.08 | 75.07 | |

[ ] denotes inferred water level values Data Status: Verified

## 4.4. Computation of Tidal Datums and Water Level Datums

### 4.4.1. National Tidal Datum Epoch

Tidal datums must be computed relative to a specific 19 years of tidal cycle adopted by the National Ocean Service (NOS) called the National Tidal Datum Epoch (NTDE). The present NTDE is the period 1960 through 1978. A primary datum determination is based directly on the average of tide observations over the 19-year Epoch period at NOS permanent long term primary control stations in the National Water Level Observation Network (NWLON). The data from NOS primary stations are used to compute datums at short term subordinate stations by reducing the data from those subordinate stations to equivalent 19 year mean values through the method of comparison of simultaneous observation.

### 4.4.2. Computational Procedures

The equivalent 19 year tidal datums for subordinate stations are computed for certain phases of the tide using tide-by-tide comparisons or monthly mean comparisons with an appropriate NOS long term control station. Accepted 19 year mean values of mean tide level (MTL), mean range (Mn), diurnal high water inequality (DHQ), diurnal low water inequality (DLQ), diurnal tide level (DTL), and great diurnal range (Gt) are required in the reduction process in which a “short series” of tide observations at any location is compared with simultaneous observations from a NOS control station. Datums are computed by the “standard” method of range ratio comparison generally on the West coast and Pacific Islands where there exists a large diurnal inequality in the low and high waters. The “modified” method of range ratio comparison is generally used on the East coast and Caribbean where small differences exist in the low and high water diurnal inequalities. For stations requiring a datum determination, at least 30 continuous days of tide observations is required for stations in the conterminous U.S. where adequate primary datum control exists. For error budget purposes, one month of data results in a datum accuracy of 0.11m (95% confidence level) for Stations in the Gulf of Mexico and 0.08m (95% confidence level) for east and West Coast stations. Examples of a tide by tide and a monthly mean simultaneous comparison for datum determination are found in Figures 4.5 and 4.6. Descriptions of the tidal datum computational procedures are found in the *Tide and Current Glossary, Tidal Datum Planes, Manual of Tide Observations, NOAA Technical Report NOS 64, Tidal Datums and Their Applications (DRAFT)* and *Computational Techniques for Tidal Datums (DRAFT*)

### 4.4.3. Tidal Datum Recovery

Whenever tide stations are installed at historical sites, measures shall be taken to “recover” the established tidal datums through leveling which shall be accomplished by referencing the gauge or tide staff zero “0" to more than one existing bench mark with a published tidal elevation. Through this process, the published MLLW elevation is transferred by level differences to the “new” gauge or tide staff and compared to the MLLW elevation computed from the new data on the same zero “0.” Factors affecting the datum recovery (i.e., differences between old and newly computed datums) include the length of each data series used to compute the datums, the geographical location, the tidal characteristics in the region, the length of time between reoccupations, the sea level trends in the region, and the control station used. Based on all of these factors, the datum recovery can be expected to vary from +/- 0.03 m to +/- 0.08 m. Hence, this process also serves as a very useful quality control procedure. After a successful datum recovery is performed and benchmark stability is established, the historical value of Mean Lower Low Water (MLLW) shall be used as the operational datum reference for data from the gauge during hydrographic survey operations. An example of a published tidal datum sheet for a station for which datum recovery could be made is found in Figure 4.7.

# Figure 4.5

COMPARISON OF SIMULTANEOUS OBSERVATIONS FOR 98 6 15 TO 98 7 14 9/11/1998
1960-1978 TIDAL EPOCH (EXPECTED DIFFERENCE (STATION A - STATION B) = .0 HOURS)

(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER ACCEPTED TM ( 0W) TIDE TYPE (M )
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY ACCEPTED TM ( 0W) TIDE TYPE (M )

| | (A) STATION TIME OF | | | (B) STATION TIME OF | | | (A) - (B) TIME DIFFERENCE | | (A) STATION HEIGHT OF | | (B) STATION HEIGHT OF | | (A) - (B) HEIGHT DIFFERENCE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | HW HOURS | | LW HOURS | DATE | HW HOURS | LW HOURS | HW HOURS | LW HOURS | HW METERS | LW METERS | HW METERS | LW METERS | HW METERS | LW METERS |
| JUN 15 | 10.6 | 15 | 5.2 | JUN 15 | 10.4 | | .2 | | 5.248 | 4.455 | 3.459 | | 1.789 | |
| | | | 17.5 | | | 16.7 | | .8 | | 3.553 | | 1.858 | | 1.695 |
| 16 | 1.0 | 16 | 6.4 | 16 | .6 | 5.5 | .4 | .9 | 5.225 | 4.469 | 3.420 | 2.750 | 1.805 | 1.719 |
| | 11.9 | | 18.4 | | 11.5 | 17.7 | .4 | . 7 | 5.169 | 3.694 | 3.391 | 2.019 | 1.778 | 1.675 |
| 17 | 1.6 | 17 | 7.6 | 17 | 1.4 | 6.6 | .2 | 1.0 | 5.304 | 4.304 | 3.509 | 2.638 | 1.795 | 1.666 |
| | 13.1 | | 19.3 | | 12.6 | 18.7 | .5 | .6 | 5.057 | 3.841 | 3.285 | 2.185 | 1.772 | 1.656 |
| 18 | 2.5 | 18 | 8.6 | 18 | 2.1 | 7.6 | .4 | 1.0 | 5.378 | 4.112 | 3.585 | 2.411 | 1.793 | 1.701 |
| | 14.3 | | 20.2 | | 14.0 | 19.3 | .3 | .9 | 4.948 | 3.887 | 3.162 | 2.229 | 1.786 | 1.658 |
| 19 | 3.3 | 19 | 9.6 | 19 | 2.8 | 8.7 | .5 | .9 | 5.450 | 3.911 | 3.653 | 2.197 | 1.797 | 1.714 |
| | 15.9 | | 21.2 | | 15.6 | 20.6 | .3 | .6 | 4.972 | 4.041 | 3.173 | 2.326 | 1.799 | 1.715 |
| 20 | 4.0 | 20 | 10.6 | 20 | 3.6 | 9.9 | .4 | .7 | 5.581 | 3.698 | 3.786 | 1.955 | 1.795 | 1.743 |
| | 17.2 | | 22.2 | | 16.7 | 21.5 | .5 | .7 | 5.009 | 4.157 | 3.208 | 2.423 | 1.801 | 1.734 |
| 21 | 4.7 | 21 | 11.6 | 21 | 4.4 | 10.9 | .3 | .7 | 5.677 | 3.495 | 3.870 | 1.762 | 1.807 | 1.733 |
| | 18.2 | | 23.1 | | 17.8 | 22.6 | .4 | .5 | 5.072 | 4.195 | 3.261 | 2.450 | 1.811 | 1.745 |
| 22 | 5.5 | 22 | 12.6 | 22 | 5.2 | 11.8 | .3 | .8 | 5.725 | 3.362 | 3.935 | 1.635 | 1.790 | 1.727 |
| | 19.2 | 23 | .1 | | 18.8 | 23.5 | .4 | .6 | 5.102 | 4.258 | 3.290 | 2.505 | 1.812 | 1.753 |
| 23 | 6.2 | | 13.6 | 23 | 6.0 | 12.5 | .2 | 1.1 | 5.748 | 3.257 | 3.943 | 1.550 | 1.805 | 1.707 |
| | 20.3 | | | | 19.8 | | .5 | | 5.144 | | 3.329 | | 1.815 | |
| 24 | 7.2 | 24 | 1.0 | 24 | 6.8 | .3 | .4 | .7 | 5.759 | 4.339 | 3.951 | 2.587 | 1.808 | 1.752 |
| | 21.1 | | 14.3 | | 20.6 | 13.3 | .5 | 1.0 | 5.198 | 3.249 | 3.371 | 1.514 | 1.827 | 1.735 |
| 25 | 7.7 | 25 | 1.8 | 25 | 7.5 | 1.1 | .2 | .7 | 5.708 | 4.355 | 3.892 | 2.625 | 1.816 | 1.730 |
| | 22.0 | | 15.0 | | 21.5 | 14.1 | .5 | .9 | 5.198 | 3.246 | 3.366 | 1.540 | 1.832 | 1.706 |
| 26 | 8.7 | 26 | 2.6 | 26 | 8.4 | 2.1 | .3 | .5 | 5.559 | 4.363 | 3.763 | 2.625 | 1.796 | 1.738 |
| | 22.6 | | 15.6 | | 22.4 | 14.6 | .2 | 1.0 | 5.158 | 3.236 | 3.343 | 1.536 | 1.815 | 1.700 |
| 27 | 9.3 | 27 | 3.6 | 27 | 9.0 | 2.9 | .3 | .7 | 5.432 | 4.360 | 3.625 | 2.629 | 1.807 | 1.731 |
| | 23.5 | | 16.2 | | 23.1 | 15.4 | .4 | .8 | 5.195 | 3.350 | 3.382 | 1.625 | 1.813 | 1.725 |
| 28 | 10.1 | 28 | 4.4 | 28 | 9.7 | 3.7 | .4 | .7 | 5.293 | 4.389 | 3.494 | 2.661 | 1.799 | 1.728 |
| 29 | .2 | | 16.7 | | 23.8 | 16.1 | .4 | .6 | 5.190 | 3.487 | 3.376 | 1.762 | 1.814 | 1.725 |
| | 10.9 | 29 | 5.6 | 29 | 10.6 | 4.7 | .3 | .9 | 5.105 | 4.360 | 3.315 | 2.649 | 1.790 | 1.711 |
| | | | 17.6 | | | 16.8 | | .8 | | 3.605 | | 1.907 | | 1.698 |
| 30 | 1.0 | 30 | 6.6 | 30 | .6 | 5.7 | .4 | .9 | 5.150 | 4.288 | 3.354 | 2.589 | 1.796 | 1.699 |
| | 12.0 | | 18.5 | | 11.6 | 17.9 | .4 | .6 | 4.897 | 3.738 | 3.120 | 2.077 | 1.777 | 1.661 |
| JUL 1 | 1.6 | 1 | 7.8 | JUL 1 | 1.4 | 6.8 | .2 | 1.0 | 5.123 | 4.195 | 3.337 | 2.520 | 1.786 | 1.675 |
| | 13.1 | | 19.2 | | 12.6 | 18.5 | .5 | .7 | 4.764 | 3.899 | 2.995 | 2.253 | 1.769 | 1.646 |
| 2 | 2.4 | 2 | 8.8 | 2 | 2.0 | 7.8 | .4 | 1.0 | 5.161 | 4.112 | 3.392 | 2.434 | 1.769 | 1.678 |
| | 14.3 | | 20.0 | | 13.9 | 19.4 | .4 | .6 | 4.713 | 4.078 | 2.950 | 2.406 | 1.763 | 1.672 |
| 3 | 3.1 | 3 | 9.9 | 3 | 2.6 | 9.1 | .5 | .8 | 5.232 | 4.036 | 3.458 | 2.366 | 1.774 | 1.670 |
| | 15.6 | | 20.8 | | 15.2 | 20.1 | .4 | .7 | 4.697 | 4.200 | 2.940 | 2.498 | 1.757 | 1.702 |
| 4 | 3.7 | 4 | 10.4 | 4 | 3.2 | 9.7 | .5 | .7 | 5.301 | 3.895 | 3.524 | 2.209 | 1.777 | 1.686 |
| | 16.7 | | 21.8 | | 16.5 | 21.1 | .2 | .7 | 4.751 | 4.326 | 2.987 | 2.612 | 1.764 | 1.714 |
| 5 | 4.2 | 5 | 11.1 | 5 | 4.0 | 10.3 | .2 | .8 | 5.365 | 3.737 | 3.584 | 2.017 | 1.781 | 1.720 |
| | 17.9 | | 22.7 | | 17.6 | 22.0 | .3 | .7 | 4.833 | 4.384 | 3.053 | 2.644 | 1.780 | 1.740 |
| 6 | 4.8 | 6 | 11.8 | 6 | 4.6 | 11.1 | .2 | .7 | 5.442 | 3.620 | 3.656 | 1.913 | 1.786 | 1.707 |
| | 18.7 | | 23.5 | | 18.3 | 22.7 | .4 | .8 | 4.905 | 4.418 | 3.124 | 2.681 | 1.781 | 1.737 |
| 7 | 5.6 | 7 | 12.6 | 7 | 5.1 | 11.8 | .5 | .8 | 5.506 | 3.532 | 3.710 | 1.812 | 1.796 | 1.720 |
| | 19.5 | 8 | .2 | | 19.1 | 23.4 | .4 | .8 | 4.991 | 4.434 | 3.193 | 2.697 | 1.798 | 1.737 |

# Figure 4.5 (cont.)

COMPARISON OF SIMULTANEOUS OBSERVATIONS FOR 98 6 15 TO 98 7 14 9/11/1998
1960-1978 TIDAL EPOCH (EXPECTED DIFFERENCE (STATION A - STATION B) = .0 HOURS)

(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER ACCEPTED TM ( 0W) TIDE TYPE (M )
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY ACCEPTED TM ( 0W) TIDE TYPE (M )

| | (A) STATION TIME OF | | | | (B) STATION TIME OF | | (A) - (B) TIME DIFFERENCE | | (A) STATION HEIGHT OF | | (B) STATION HEIGHT OF | | (A) - (B) HEIGHT DIFFERENCE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | HW HOURS | | LW HOURS | DATE | HW HOURS | LW HOURS | HW HOURS | LW HOURS | HW METERS | LW METERS | HW METERS | LW METERS | HW METERS | LW METERS |
| JUL 8 | 6.0 | 8 | 13.2 | JUL 8 | 5.8 | 12.4 | .2 | .8 | 5.568 | 3.463 | 3.754 | 1.729 | 1.814 | 1.734 |
| | 20.2 | | | | 19.7 | | .5 | | 5.024 | | 3.222 | | 1.802 | |
| 9 | 6.7 | 9 | .7 | 9 | 6.3 | .1 | .4 | .6 | 5.589 | 4.445 | 3.789 | 2.702 | 1.800 | 1.743 |
| | 20.8 | | 13.9 | | 20.4 | 13.1 | .4 | .8 | 5.092 | 3.402 | 3.285 | 1.669 | 1.807 | 1.733 |
| 10 | 7.6 | 10 | 1.6 | 10 | 7.3 | .9 | .3 | .7 | 5.605 | 4.442 | 3.794 | 2.709 | 1.811 | 1.733 |
| | 21.5 | | 14.5 | | 21.1 | 13.7 | .4 | .8 | 5.120 | 3.349 | 3.306 | 1.627 | 1.814 | 1.722 |
| 11 | 8.4 | 11 | 2.2 | 11 | 8.0 | 1.6 | .4 | .6 | 5.527 | 4.342 | 3.712 | 2.613 | 1.815 | 1.729 |
| | 22.1 | | 15.2 | | 21.7 | 14.4 | .4 | .8 | 5.112 | 3.294 | 3.302 | 1.578 | 1.810 | 1.716 |
| 12 | 8.8 | 12 | 3.2 | 12 | 8.8 | 2.5 | .0 | .7 | 5.445 | 4.309 | 3.638 | 2.584 | 1.807 | 1.725 |
| | 22.7 | | 15.8 | | 22.3 | 15.1 | .4 | .7 | 5.163 | 3.334 | 3.355 | 1.608 | 1.808 | 1.726 |
| 13 | 9.6 | 13 | 3.8 | 13 | 9.3 | 3.1 | .3 | .7 | 5.354 | 4.264 | 3.547 | 2.529 | 1.807 | 1.735 |
| | 23.5 | | 16.6 | | 23.1 | 15.6 | .4 | 1.0 | 5.243 | 3.438 | 3.419 | 1.691 | 1.824 | 1.747 |
| 14 | 10.6 | 14 | 4.7 | 14 | 10.1 | 4.1 | .5 | .6 | 5.235 | 4.262 | 3.443 | 2.521 | 1.792 | 1.741 |
| | | | 17.1 | | 23.9 | 16.5 | | .6 | | 3.521 | 3.483 | 1.800 | | 1.721 |

| | | | HHW | HLW | HHW | HLW | HHW | HLW |
|---|---|---|---|---|---|---|---|---|
| SUMS | | | 152.420 | 120.010 | 102.090 | 71.841 | 50.330 | 48.169 |
| ITEMS | | | 28 | 28 | 28 | 28 | 28 | 28 |
| MEANS | | | 5.444 | 4.286 | 3.646 | 2.566 | 1.797 | 1.720 |
| | | | LHW | LLW | LHW | LLW | LHW | LLW |
| SUMS | 20.6 | 43.5 | 146.092 | 103.320 | 93.990 | 53.800 | 52.102 | 49.520 |
| ITEMS | 57 | 57 | 29 | 29 | 29 | 29 | 29 | 29 |
| MEANS | .36 | .76 | 5.038 | 3.563 | 3.241 | 1.855 | 1.797 | 1.708 |

COMPARISON OF SIMULTANEOUS OBSERVATIONS FOR 98 6 15 TO 98 7 14 9/11/1998
1960-1978 TIDAL EPOCH (EXPECTED DIFFERENCE (STATION A - STATION B) = .0 HOURS)

(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER ACCEPTED TM ( 0W) TIDE TYPE (M )
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY ACCEPTED TM ( 0W) TIDE TYPE (M )

ERROR SCAN FOR TIME DIFFERENCE OF HW
STANDARD DEVIATION= .111
ERROR IN 98 7 12 88 (SUBORDINATE STATION) .0
ERROR SCAN FOR TIME DIFFERENCE OF LW
STANDARD DEVIATION= .141
ERROR IN 98 6 23 136 (SUBORDINATE STATION) 1.1
ERROR SCAN FOR HEIGHT DIFFERENCE OF HHW
STANDARD DEVIATION= .013
ERROR IN 98 7 2 24 (SUBORDINATE STATION) 1.769
ERROR SCAN FOR HEIGHT DIFFERENCE OF LHW
STANDARD DEVIATION= .020
ERROR SCAN FOR HEIGHT DIFFERENCE OF HLW
STANDARD DEVIATION= .026
ERROR IN 98 6 17 76 (SUBORDINATE STATION) 1.666
ERROR IN 98 6 18 202 (SUBORDINATE STATION) 1.658
ERROR SCAN FOR HEIGHT DIFFERENCE OF LLW
STANDARD DEVIATION= .027
ERROR IN 98 7 1 192 (SUBORDINATE STATION) 1.646

# Figure 4.5 (cont.)

COMPARISON OF SIMULTANEOUS OBSERVATIONS FOR 98 6 15 TO 98 7 14 9/11/1998
1960-1978 TIDAL EPOCH (EXPECTED DIFFERENCE (STATION A - STATION B) = .0 HOURS)

(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER ACCEPTED TM ( 0W) TIDE TYPE (M )
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY ACCEPTED TM ( 0W) TIDE TYPE (M )

MEAN DIFFERENCE IN HIGH ( .36) AND LOW ( .76) WATER INTERVALS

| | |
|---|---|
| MEAN HHW HEIGHT AT (A) = 5.444 | MEAN HLW HEIGHT AT (A) = 4.286 |
| MEAN LHW HEIGHT AT (A) = 5.038 | MEAN LLW HEIGHT AT (A) = 3.563 |
| DHQ AT (A) = .207 | DLQ AT (A) = .355 |
| MEAN HW HEIGHT AT (A) = 5.237 | MEAN LW HEIGHT AT (A) = 3.918 |
| MN AT (A) = 1.319 | MTL AT (A) = 4.578 |
| GT AT (A) = 1.881 | DTL AT (A) = 4.503 |

| | |
|---|---|
| MEAN HHW DIFFERENCE = 1.797 | MEAN HLW DIFFERENCE = 1.720 |
| MEAN LHW DIFFERENCE = 1.797 | MEAN LLW DIFFERENCE = 1.708 |
| DHQ DIFFERENCE = .000 | DLQ DIFFERENCE = .006 |
| MEAN HW DIFFERENCE = 1.797 | MEAN LW DIFFERENCE = 1.714 |
| MN DIFFERENCE = .083 | MTL DIFFERENCE = 1.755 |
| GT DIFFERENCE = .090 | DTL DIFFERENCE = 1.753 |
| MN RATIO = 1.067 | DHQ RATIO = 1.002 |
| GT RATIO = 1.050 | DLQ RATIO = 1.018 |
| MSL AT (A) = 4.570 | |
| MSL AT (B) = 2.804 | |
| MSL DIFFERENCE = 1.766 | |

| | HWI HOURS | LWI HOURS | MTL METERS | MN METERS | DHQ METERS | DLQ METERS |
|---|---|---|---|---|---|---|
| ACCEPTED FOR B | 7.56 | .83 | 2.728 | 1.250 | .183 | .344 |
| DIFFERENCES AND RATIOS | .36 | .76 | 1.755 | 1.067 | 1.002 | 1.018 |
| CORRECTED FOR A | 7.92 | 1.59 | 4.483 | 1.334 | .183 | .351 |

| | MSL METERS | DTL METERS | GT METERS |
|---|---|---|---|
| ACCEPTED FOR B | 2.713 | 2.646 | 1.777 |
| DIFFERENCES AND RATIOS | 1.766 | 1.753 | 1.050 |
| CORRECTED FOR A | 4.479 | 4.398 | 1.866 |

MRR METHOD
MHHW= 5.331 MLLW= 3.465
DHQ = .181 DLQ = .351

SRANDARD METHOD
MHHW= 5.334 MLW = 3.816
MHW = 5.150 MLLW= 3.466

DIRECT METHOD

| | MHHW METERS | MHW METERS | MLW METERS | MLLW METERS |
|---|---|---|---|---|
| ACCEPTED FOR B | 3.536 | 3.353 | 2.103 | 1.759 |
| DIFFERENCES AND RATIOS | 1.797 | 1.797 | 1.714 | 1.708 |
| CORRECTED FOR A | 5.333 | 5.150 | 3.817 | 3.466 |

MN = 1.333
GT = 1.867

**FIGURE 4.6 Monthly Mean Simultaneous Comparison Example**

COMPARISON OF MONTHLY MEANS ( JAN-98 - JUN-98) 1960-78 TIDAL EPOCH
(A) SUBORDINATE: 9414863 RICHMOND, CA TM (000W) TIDE TYPE:MIXED
(B) CONTROL: 9414290 SAN FRANCISCO, CA TM (000W) TIDE TYPE:MIXED

| month/year | | MTL | | | MSL | | | HWI | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | A - B | A | B | A - B | A | B | A - B |
| | meters | meters | meters | meters | meters | meters | hours | hours | hours |
| Jan-98 | 4.736 | 3.001 | 1.735 | 4.726 | 2.981 | 1.745 | 7.900 | 7.510 | 0.390 |
| Feb-98 | 4.841 | 3.103 | 1.738 | 4.839 | 3.082 | 1.757 | 7.900 | 7.580 | 0.320 |
| Mar-98 | 4.624 | 2.883 | 1.741 | 4.615 | 2.859 | 1.756 | 7.840 | 7.520 | 0.320 |
| Apr-98 | 4.542 | 2.798 | 1.744 | 4.532 | 2.776 | 1.756 | 7.880 | 7.530 | 0.350 |
| May-98 | 4.562 | 2.811 | 1.751 | 4.547 | 2.787 | 1.760 | 7.890 | 7.540 | 0.350 |
| Jun-98 | 4.600 | 2.849 | 1.751 | 4.588 | 2.826 | 1.762 | 7.930 | 7.570 | 0.360 |
| month/year | | LWI | | | MN | | | DHQ | |
| | A | B | A - B | A | B | A/B | A | B | A/B |
| | hours | hours | hours | meters | meters | ratio | meters | meters | ratio |
| Jan-98 | 1.460 | 0.790 | 0.670 | 1.367 | 1.287 | 1.062 | 0.207 | 0.213 | 0.972 |
| Feb-98 | 1.570 | 0.820 | 0.750 | 1.208 | 1.101 | 1.097 | 0.161 | 0.183 | 0.880 |
| Mar-98 | 1.430 | 0.660 | 0.770 | 1.321 | 1.215 | 1.087 | 0.118 | 0.125 | 0.944 |
| Apr-98 | 1.450 | 0.660 | 0.790 | 1.309 | 1.210 | 1.082 | 0.111 | 0.117 | 0.949 |
| May-98 | 1.460 | 0.690 | 0.770 | 1.306 | 1.217 | 1.073 | 0.155 | 0.158 | 0.981 |
| Jun-98 | 1.490 | 0.720 | 0.770 | 1.292 | 1.205 | 1.072 | 0.194 | 0.196 | 0.990 |
| month/year | | DLQ | | | MHW | | | MLW | |
| | A | B | A/B | A | B | A - B | A | B | A - B |
| | meters | meters | meters | ratio | meters | meters | meters | meters | meters |
| Jan-98 | 0.331 | 0.337 | 0.982 | 5.420 | 3.644 | 1.776 | 4.053 | 2.357 | 1.696 |
| Feb-98 | 0.251 | 0.261 | 0.962 | 5.445 | 3.653 | 1.792 | 4.237 | 2.552 | 1.685 |
| Mar-98 | 0.210 | 0.207 | 1.014 | 5.284 | 3.490 | 1.794 | 3.983 | 2.275 | 1.708 |
| Apr-98 | 0.279 | 0.268 | 1.041 | 5.196 | 3.403 | 1.793 | 3.887 | 2.193 | 1.694 |
| May-98 | 0.336 | 0.328 | 1.024 | 5.215 | 3.420 | 1.795 | 3.909 | 2.203 | 1.706 |
| Jun-98 | 0.360 | 0.352 | 1.023 | 5.246 | 3.452 | 1.794 | 3.954 | 2.247 | 1.707 |
| month/year | | DRL(TL) | | | GT | | | MHHW | |
| | A | B | A - B | A | B | A/B | A | B | A - B |
| | meters | meters | meters | meters | meters | ratio | meters | meters | meters |
| Jan-98 | 4.675 | 2.939 | 1.736 | 1.905 | 1.837 | 1.037 | 5.627 | 3.857 | 1.770 |
| Feb-98 | 4.806 | 3.063 | 1.743 | 1.640 | 1.545 | 1.061 | 5.626 | 3.836 | 1.790 |
| Mar-98 | 4.578 | 2.841 | 1.737 | 1.649 | 1.547 | 1.066 | 5.402 | 3.615 | 1.787 |
| Apr-98 | 4.458 | 2.723 | 1.735 | 1.699 | 1.595 | 1.065 | 5.307 | 3.520 | 1.787 |
| May-98 | 4.471 | 2.726 | 1.745 | 1.797 | 1.703 | 1.055 | 5.370 | 3.578 | 1.792 |
| Jun-98 | 4.517 | 2.772 | 1.745 | 1.846 | 1.753 | 1.053 | 5.440 | 3.648 | 1.792 |
| month/year | | MLLW | | | | | | | |
| | A | B | A - B | | | | | | |
| | meters | meters | meters | | | | | | |
| Jan-98 | 3.722 | 2.020 | 1.702 | | | | | | |
| Feb-98 | 3.986 | 2.291 | 1.695 | | | | | | |
| Mar-98 | 3.753 | 2.068 | 1.685 | | | | | | |
| Apr-98 | 3.608 | 1.925 | 1.683 | | | | | | |
| May-98 | 3.573 | 1.875 | 1.698 | | | | | | |
| Jun-98 | 3.594 | 1.895 | 1.699 | | | | | | |

COMPARISON OF MONTHLY MEANS ( JAN-98 - JUN-98) 1960-78 TIDAL EPOCH
(A) SUBORDINATE: 9414863 RICHMOND, CA TM (000W) TIDE TYPE:MIXED
(B) CONTROL: 9414290 SAN FRANCISCO, CA TM (000W) TIDE TYPE:MIXED

| | MTL A - B meters | MSL A - B meters | HWI A - B hours | LWI A - B hours | MN A/B ratio | DHQ A/B ratio | DLQ A/B ratio |
|---|---|---|---|---|---|---|---|
| months | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| sums | 10.460 | 10.536 | 2.090 | 4.520 | 6.473 | 5.825 | 6.046 |
| means | 1.743 | 1.756 | 0.348 | 0.753 | 1.079 | 0.971 | 1.008 |
| accepted B | 2.728 | 2.713 | 7.560 | 0.830 | 1.250 | 0.183 | 0.344 |
| corrected A | 4.471 | 4.469 | 7.908 | 1.583 | 1.349 | 0.178 | 0.347 |

| | MHW A - B meters | MLW A - B meters | DRL(TL) A - B meters | GT A/B ratio | MHHW A - B meters | MLLW A - B meters |
|---|---|---|---|---|---|---|
| months | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| sums | 10.744 | 10.176 | 10.441 | 6.337 | 10.718 | 10.162 |
| means | 1.791 | 1.696 | 1.740 | 1.056 | 1.786 | 1.694 |
| accepted B | 3.353 | 2.103 | 2.646 | 1.777 | 3.536 | 1.759 |
| corrected A | 5.144 | 3.799 | 4.386 | 1.877 | 5.322 | 3.453 |

| METHOD | DATUM | VALUE meters |
|---|---|---|
| MRR | MHHW | 5.325 |
| MRR | MLLW | 3.448 |
| MRR | DHQ | 0.179 |
| MRR | DLQ | 0.349 |
| STANDARD | MHW | 5.146 |
| STANDARD | MLW | 3.797 |
| STANDARD | MHHW | 5.323 |
| STANDARD | MLLW | 3.450 |
| DIRECT | MN | 1.345 |
| DIRECT | GT | 1.870 |
| DIRECT | DHQ | 0.179 |
| DIRECT | DLQ | 0.346 |

FINAL/PRELIMINARY DATUMS
METHOD : STANDARD 1960-78 EPOCH

| DATUM | VALUE meters |
|---|---|
| MHHW | 5.323 |
| MHW | 5.146 |
| MTL | 4.471 |
| MSL | 4.469 |
| DRL(TL) | 4.386 |
| MLW | 3.797 |
| MLLW | 3.450 |
| MN | 1.349 |
| GT | 1.873 |
| DHQ | 0.178 |
| DLQ | 0.347 |

COMPARISON OF MONTHLY MEANS ( JAN-98 - JUN-98) 1960-78 TIDAL EPOCH
(A) SUBORDINATE: 9414863 RICHMOND, CA TM (000W) TIDE TYPE:MIXED
(B) CONTROL: 9414290 SAN FRANCISCO, CA TM (000W) TIDE TYPE:MIXED

OUTLIER REPORT: MAXIMUMS AND MINIMUMS WHEN INDIVIDUAL MONTHLY MEAN DIFFERENCE EXCEEDS TWO STANDARD DEVIATIONS FROM OVERALL MEAN

| | MTL | MSL | HWI | LWI | MN | DHQ | DLQ |
|---|---|---|---|---|---|---|---|
| STD.DEV. | 0.004 | 0.003 | 0.018 | 0.019 | 0.008 | 0.012 | 0.017 |
| MAXIMUM | 1.752 | 1.762 | 0.384 | 0.791 | 1.095 | 0.994 | 1.041 |
| MINIMUM | 1.734 | 1.750 | 0.313 | 0.715 | 1.062 | 0.948 | 0.974 |
| month/year | | | | | | | |
| Jan-98 | | 1.745 | 0.390 | 0.670 | 1.062 | | |
| Feb-98 | | | | | 1.097 | | 0.962 |
| Mar-98 | | | | | | 0.944 | |
| Apr-98 | | | | | | | 1.041 |
| May-98 | | | | | | | |
| Jun-98 | | | | | | | |

| | MHW | MLW | DTL | GT | MHHW | MLLW |
|---|---|---|---|---|---|---|
| STD.DEV. | 0.003 | 0.006 | 0.003 | 0.006 | 0.004 | 0.004 |
| MAXIMUM | 1.796 | 1.708 | 1.746 | 1.068 | 1.794 | 1.703 |
| MINIMUM | 1.785 | 1.684 | 1.734 | 1.045 | 1.779 | 1.685 |
| month/year | | | | | | |
| Jan-98 | 1.776 | | | 1.037 | 1.770 | |
| Feb-98 | | | | | | |
| Mar-98 | | | | | | |
| Apr-98 | | | | | | 1.683 |
| May-98 | | | | | | |
| Jun-98 | | | | | | |

**Figure 4.7**

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CALIFORNIA 941 4290
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE
TIDAL BENCH MARKS
THE PRESIDIO, SAN FRANCISCO
LATITUDE: 37Ε 48.4' N LONGITUDE: 122Ε 27.9' W
NOAA CHART: 18649 USGS QUAD: SAN FRANCISCO NORTH

TO REACH TIDE STATION: To reach the tide station from the intersection of U.S. Highway 101 (north) and Lincoln Boulevard (last exit before the Golden Gate toll plaza), proceed NE on Lincoln Boulevard approximately 1.6 km (1.0 mile) to Cowles Street, turn left onto Cowles Street and proceed 0.8 km (0.5 mile) to McDowell Avenue, turn left onto McDowell Avenue and proceed 0.5 km (0.3 mile)to Crissey Field Avenue, turn left onto Crissey Field Avenue and proceed 0.3 km (0.2 mile) to a stop sign, turn right and then immediately left onto Mason
street, proceed along the National Parks Service parking lot fence where Mason Street turns into Hamilton Street, and proceed 0.5 km (0.3 mile) to a parking lot at the end of the street. The tide station is located in the 2nd building on the L-shaped wooden pier formerly owned by the U.S.Coast Guard, now owned by the National Park Service.

..................................................................................

BENCH MARK STAMPING: 180 1936

MONUMENTATION: Survey Disk
AGENCY/DISK TYPE: USC&GS Tidal Bench Mark
SETTING CLASSIFICATION: Concrete Seawall
The primary bench mark is set in the top of a 0.9-m (3') high concrete seawall at the NW end of Crissy Field on the Coast Guard property, 15 m (49') east of the NE corner of the crews quarters building, 6 m (20') south of the south side of the garage building, and 1.1 m (3.5') north of an angle in the seawall.

BENCH MARK STAMPING: 181 1945

MONUMENTATION: Survey Disk
AGENCY/DISK TYPE: USC&GS Tidal Bench Mark
SETTING CLASSIFICATION: Concrete Seawall
The bench mark is set in the top of the NW corner of a seawall at the Fort Point Coast Guard Station, 62 m (204') west of the inshore end of the Coast Guard wharf, 46 m (151') NW of a flagpole, 22 m (71') NE of the north corner of Building S.F. 19.4 (paint shop and storage building), and 1.2 m (4.0') above grade.

**Figure 4.7** **(cont.)**

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CALIFORNIA 941 4290
THE PRESIDIO, SAN FRANCISCO

BENCH MARK STAMPING: 4290 J 1976
MONUMENTATION: Survey Disk
AGENCY/DISK TYPE: NOS Tidal Bench Mark
SETTING CLASSIFICATION: Copper Clad Steel Rod
The bench mark is in an elevated beach area midway between the Fort Point Coast Guard pier and the engineer's dock, 133 m (435') WNW of the west end of the seawall surrounding the Coast Guard crews quarters, 27 m (89') SW of the shoreward end of the old seaplane ramp, 18.3 m (60.0') SE of the shoreward end of the concrete discharge pipe, and 0.8 m (2.5') north of a chain link fence surrounding U.S. Army Field Maintenance Building #937. The mark is crimped to a copper-clad steel rod driven 15 m (48'), encased in a 4-inch diameter PVC pipe, and marked by a witness post.

BENCH MARK STAMPING: 4290 K 1976
MONUMENTATION: Survey Disk
AGENCY/DISK TYPE: NOS Tidal Bench Mark
SETTING CLASSIFICATION: Bedrock
The bench mark is set vertically in bedrock on the south side of Marine Drive, 24 m (79') SSW of the SE corner of National Park Service building #T989, 14.7 m (48.2') SW of Bench Mark 174 1925, and 2.4 m (8.0') south of the south curb of Marine Drive.

BENCH MARK STAMPING: BM 174 1925
MONUMENTATION: Survey Disk
AGENCY/DISK TYPE: USC&GS Tidal Bench Mark
SETTING CLASSIFICATION: Concrete Monument
The bench mark is set in a concrete monument level with the ground inside a brick circle in the pavement at the center of the Y-junction between Marine Drive and the road leading SE to Fort Winfield Scott, 38 m (125') west of the extension of the west edge of the engineer's dock where it crosses Marine Drive, 13.0 m (42.5') SW of a fire hydrant, and 8.7 m (28.5') south of the south edge of an iron manhole cover.

BENCH MARK STAMPING: BM 175 1925
MONUMENTATION: Survey Disk
AGENCY/DISK TYPE: USC&GS Tidal Bench Mark
SETTING CLASSIFICATION: Concrete Seawall
The bench mark is set in the seawall near the National Park Service building, 62.2 m (214') NE of Bench Mark 4290 L 1976, 59 m (193') west of the NW corner of the park service building, 28.9 m (94.8') WNW of the northernmost post of a pedestrian gate, 6.9 m (22.5') north of the centerline of Marine Drive, and 0.7 m (2.4') south of the north edge of the seawall. (Note: The seawall was
repaired in April 1981 and the elevation of the bench mark was changed after the repair, but the elevation seems stable since then.)

**Figure 4.7 (cont.)**

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CALIFORNIA 941 4290
THE PRESIDIO, SAN FRANCISCO

BENCH MARK STAMPING: BM 176 1925
MONUMENTATION: Survey Disk
AGENCY/DISK TYPE: USC&GS Tidal Bench Mark
SETTING CLASSIFICATION: Concrete Step
The bench mark is set in the west end of the lowest concrete step at the main entrance to the porch of the U.S. Army Logistic Control office at #651 Mason Avenue, 30 m (98') SE of the intersection of Crissy Field and Mason Avenues, 15 m (50') south of the centerline of Mason Avenue, and about 0.2 m (0.7') above the sidewalk.

BENCH MARK STAMPING: CLARK 1948
MONUMENTATION: Survey Disk
AGENCY/DISK TYPE: USC&GS Triangulation Mark
SETTING CLASSIFICATION: Concrete Seawall
The bench mark is set in the top of a concrete seawall, about 549 m (1800') NW of the Fort Point Coast Guard station, 24.2 m (79.5') west of the west edge of the engineer's dock, 6.9 m (22.5') NE of the NW corner of corrugated iron building #985, 3.0 m (10') west of the NW corner of a stucco paint locker building, and about 1.1 m (3.6') above ground.

BENCH MARK STAMPING: NO 2 1948
MONUMENTATION: Survey Disk
AGENCY/DISK TYPE: USC&GS Reference Mark
SETTING CLASSIFICATION: Concrete Seawall
The bench mark is set flush in the top of a concrete seawall, 11.4 m (37.5') west of the west edge of the engineer's dock, 8.1 m (26.5') NE of the NE corner of corrugated iron building #985, and about 0.9 m (3.0') above ground.

## Figure 4.7 (cont.)

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CALIFORNIA 941 4290
THE PRESIDIO, SAN FRANCISCO

Tidal datums at THE PRESIDIO, SAN FRANCISCO are based on the following:

| | | |
|---|---|---|
| LENGTH OF SERIES | = | 19 YEARS |
| TIME PERIOD | = | 1960-1978 |
| TIDAL EPOCH | = | 1960-1978 |
| CONTROL TIDE STATION | = | |

Elevations of tidal datums referred to mean lower low water (MLLW) are as follows:

| | | |
|---|---|---|
| HIGHEST OBSERVED WATER LEVEL (01/27/1983) | = | 8.87 FEET |
| MEAN HIGHER HIGH WATER (MHHW) | = | 5.83 FEET |
| MEAN HIGH WATER (MHW) | = | 5.23 FEET |
| MEAN TIDE LEVEL (MTL) | = | 3.18 FEET |
| MEAN SEA LEVEL (MSL) | = | 3.13 FEET |
| MEAN LOW WATER (MLW) | = | 1.13 FEET |
| *NORTH AMERICAN VERTICAL DATUM-1988 (NAVD) | = | 0.14 FEET |
| MEAN LOWER LOW WATER (MLLW) | = | 0.00 FEET |
| LOWEST OBSERVED WATER LEVEL (12/17/1933) | = | -2.67 FEET |

*NAVD is based on elevations published in Quad 371221, 1993, and NOS leveling of 1995.

Bench mark elevation information:

| | ELEVATION IN FEET ABOVE: | |
|---|---|---|
| BENCH MARK STAMPING | MLLW | MHW |
| 180 1936 | 13.24 | 8.01 |
| 181 1945 | 13.29 | 8.06 |
| 4290 J 1976 | 11.18 | 5.95 |
| 4290 K 1976 | 19.31 | 14.08 |
| BM 174 1925 | 16.65 | 11.42 |
| BM 175 1925 | 13.84 | 8.61 |
| BM 176 1925 | 15.99 | 10.76 |
| CLARK 1948 | 14.08 | 8.85 |
| NO 2 1948 | 14.04 | 8.81 |

## Figure 4.7 (cont.)

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CALIFORNIA 941 4290
THE PRESIDIO, SAN FRANCISCO

MSL is the local mean sea level and should not be confused with the fixed datums of NGVD (sometimes referred to as Sea Level Datum of 1929) or NAVD 88. NGVD is a fixed datum adopted as a standard geodetic reference for heights. It was derived from a general adjustment of the first order leveling nets of the U.S. and Canada. Mean sea level was held fixed as observed at 26 stations in the U.S. and Canada. Numerous adjustments have been made since originally established in 1929.

NAVD 88 involved a simultaneous, least squares, minimum-constraint adjustment of Canadian-Mexican-United States leveling observations. Local mean sea level at Father Point/Rimouski, Canada was held fixed as the single constraint. These fixed datums do not take into account the changing stands of sea level and because they represent a "best" fit over a broad area, their relationship to local mean sea level is not consistent from one location to another.